RECON/OPTICAL, INC

KA-91C PANORAMIC CAMERA

TD-806-D1
Revised March 26, 2002

INTRODUCTION

The KA-91C Panoramic Camera shown, in Figure 1, is a prism pan camera featuring an 18-inch focal length (fl), f/4.0 optical lens cone, and a direct-drive, 5-inch format pan/frame film magazine. This document describes the key features of this camera including selectable sector scan, data annotation, Forward Motion Compensation (FMC), roll stabilization and automatic exposure control with manual override.

The predecessor of the KA-91C is the KA-91B. The mechanical configuration of the camera was dictated by the use of the camera in the RF-4C aircraft. The prime difference between the KA-91B and the KA-91C camera is the incorporation of the direct-drive pan/frame magazine. This magazine is capable of operating on both the KA-91C pan cone and the KS-87E framing camera (the for-runner of the KS-87E is the KS-87B). Leading particulars for the KA-91C camera are as given in table 1.

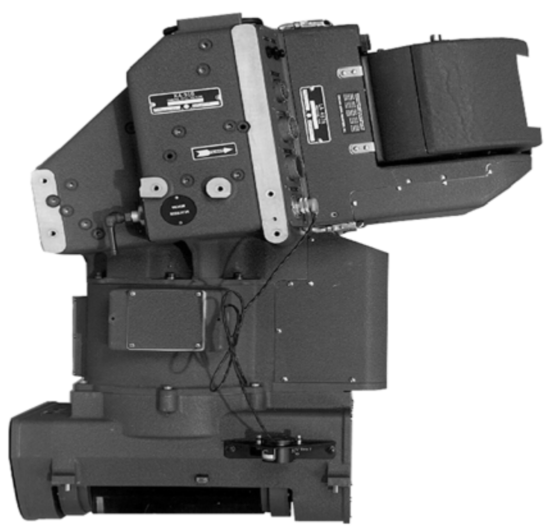


Figure 1. KA-91C Panoramic Camera

Table 1

KA-91C Leading Particulars

Lens	18-inch fl, f/4.0
Dynamic bench resolution	45 lp/mm EK 3404 film
Film	5-inch aerial roll film black and white or color, un-perforated
Film capacity	1000 ft 2.5-mil, cassette load
Data annotation	LED data, fixed mission data and serial events along film edge
Film flattening	Vacuum platen
Filters	0.6 ND, W-12, W-25
Roll rate compensation	Self-contained gyro, compensates up to 10̃/s.
Focus	Fixed, 40,000 ft range, 6,000 ft pressure, 73 Deg. F.
Overlap	Controlled from the Camera Control Panel
Shutter	Capping type
Exposure control	Self-contained automatic, 1/100 to1/1500 s with manual override
Power	28 Vdc, 3.5 A, 115/208 VRMS, 400 Hz, 2 Amps/phase
Scan angles	60 deg, and 93 deg
Cycle rates maximum	1.33 cycles/s @ 60 deg; 1.00 cycle/s @ 93deg
FMC maximum	2.63 inches/sec @ 60deg, and 1.98 inches/sec @ 93deg
V/H max	.086, kn/ft @ 60deg, and .065 kn/ft @ 93deg.

FUNCTIONAL DESCRIPTION

The KA-91C camera provides wide-angle coverage of the terrain through the use of a double-dove prism located in front of the camera lens. The use of the prism provides an extremely easy method of increasing the angular coverage of the lens in the direction perpendicular to the camera's line of flight.

The combined lens/prism system generates an image at the film plane moving at a rate shown in the following equation:

$$vi = 2 \times F_L \times W_P$$

where:

vi = image velocity at the film plane (inches/s)

F_L = lens focal length (inches)

W_P = prism rotation velocity (rad/s)

To produce a panoramic photograph, the generated image must be synchronized with the film by moving the film at a rate equal to the generated image rate per the following equation:

$$vi = vf$$

where:

vf = velocity of film (inches/s)

This synchronization permits the viewed scene to be recorded on the film as the film moves past the recording area. In the KA-91C, as in all of ROI's prism panoramic cameras, the film runs at a constant rate of 40 inches/s. The density of the exposure is controlled by two slit blades operated by the camera's automatic exposure control system.

Operating components, shown in figure 2, include a moving film transport synchronized electronically with the scanning prism assembly, a moving lens assembly for FMC, and a capping shutter to provide for interframe spacing. With the exception of the Velocity/Height (V/H) signals, data annotation information, and the camera cycle pulses, all other electronics are self-contained within the camera.

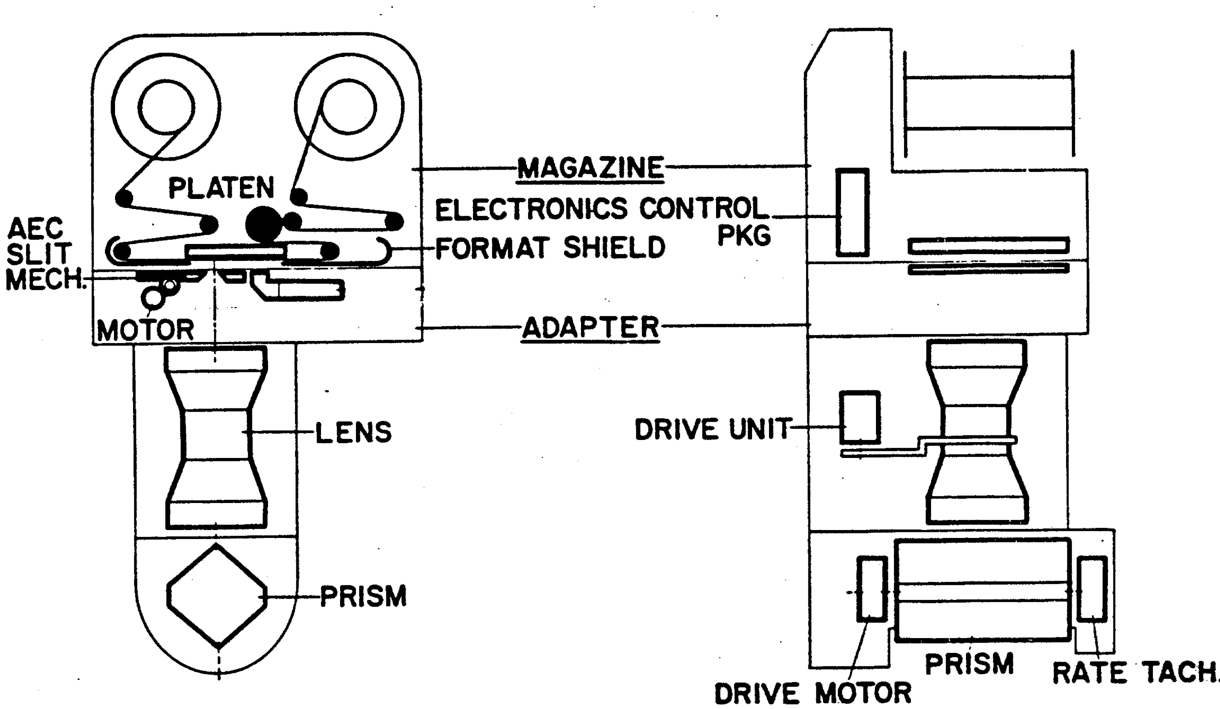
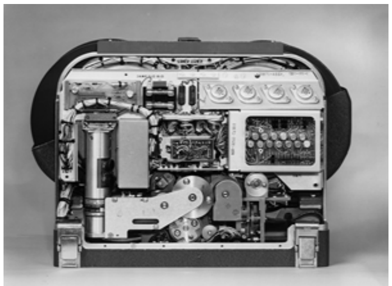


Figure 2 Operating Components

DIRECT-DRIVE PAN/FRAME MAGAZINE

The direct-drive pan/frame magazine is a major upgrade to the KS-87E/KA-91C family of cameras. This dual-function magazine is capable of taking both panoramic and framing photographs when used with the appropriate camera. Figures 3 and 4 are comparison photos of the original gear-driven magazines used on the KS-87B through KS-87D1 cameras. Figure 3 is a design similar to the one used on the KA-91B camera. Figure 4 shows the upgraded direct-drive magazine capable of operation on both the KA-91C and KS-87E cameras.

The advantages of the upgraded magazine are numerous. Foremost is that one magazine can now be inventoried and used on both the KA-91C and KS-87E camera. This advantage substantially reduces the required inventory of spare parts and reduces maintenance times and subsequent repair costs. Additionally, the unique mechanical timing settings for the KS-87 gear-driven units are now eliminated. Analysis indicates that the Mean-Time-Between-Failure (MTBF) increases from approximately 1300 hours to over 4000 hours for the direct-drive configuration.



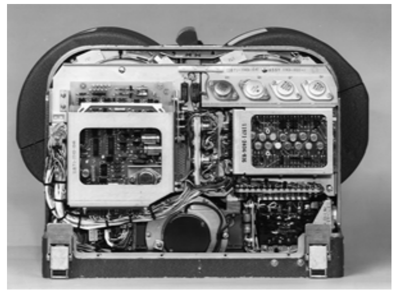


Figure 3. Original KS-87 Magazine **Figure 4. Upgraded Magazine**

OPERATION

During panoramic operation, the magazine again remains in a basic standby mode of operation until the camera receives a trip pulse. Upon receipt of the trip pulse, the film in the magazine is accelerated to a velocity of 40 inches/s, a rate that remains constant during the entire duration of the photograph. Upon completion of the photograph, the magazine, through signals from the pan cone assembly, command the magazine to return to standby until the next camera trip pulse is received. A crystal-controlled oscillator, a digital tachometer and a phase-lock servo loop control the film scan rate.

DATA ANNOTATION

Two types of data annotation are available in the KA-91C:

- Fixed data, which includes both, fixed mission data that can be changed by the camera operator, and serial event data indicating frame count.
- Active data derived from aircraft navigation equipment and an onboard data annotation system control unit.

The active data is written by using a seven-unit LED array, shown in figure 5, mounted in the magazine film platen at the edge of the format. This array prints data along the edge of the film while the film is being moved to take a photograph. As an analogy, it is like a dot matrix printer except that the film moves rather than the print head. Data intensity is controlled by the length of time the LED array receives a signal from the data annotation system. A pulse generator, coupled to the metering roller that drives the film, generates a series of pulses at approximately 7900 Hz with each pulse forming the next line of character building dots on the film. A typical character will consist of a height of seven dots and a width of five dots. Approximately 30 characters can be printed on 1 inch (2.54 cm) of film. A gate signal activated during film recycle, also generated by the camera, determines when to begin the printing sequence.

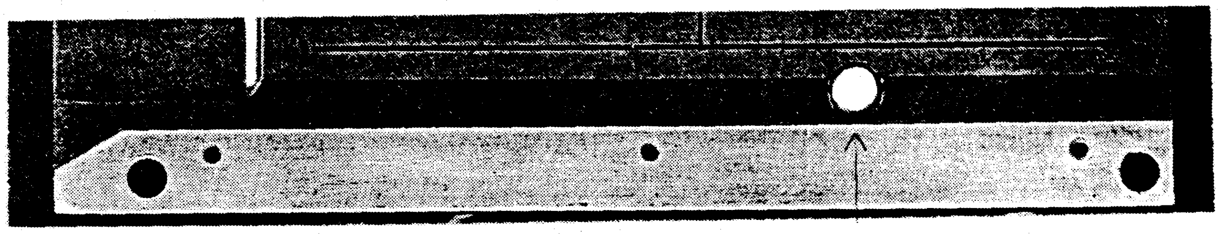


Figure 5. Platen with LED

FORWARD MOTION COMPENSATION

FMC is required to avoid image blur caused by forward motion of the vehicle. However, the moving film transport system used in the conventional frame camera, i.e., KS-87E, cannot be used in a pan camera because the film is already moving synchronously with the prism to scan the terrain. In addition, as the terrain is scanned, the amount of FMC required changes, varying directly with the sine of the depression angle as shown in the following equation:

$$FMC = 1.69\ V/H\ F_L\ \sin\phi$$

where:

FMC	=	forward motion compensation required (inches/s)
V	=	forward velocity of aircraft (kn)
H	=	vertical altitude above terrain (ft)
F_L	=	lens focal length
ϕ	=	depression angle as referenced to the horizon

A moving lens technique is used to achieve FMC. Mounted on linear bearings, the lens is moved in the reverse direction of the aircraft's forward motion at a rate satisfying the above equation.

Figure 6 shows the principles used to satisfy the above equation. To compensate for the changing FMC requirement as the terrain is scanned, the V/H signal input from the aircraft Camera Control Panel (CCP) is modified by a sine function potentiometer mechanically coupled by a 2:1 gear train to the scanning prism. The purpose of the 2:1 coupling is that for every 1 deg. of prism rotation, a resultant 2 degs. of ground coverage is obtained. As an example, to scan a 60 deg. ground coverage, the prism moves only 30 degs. As the prism scans the terrain, the input V/H signal is modified by the sine potentiometer, resulting in a signal proportional to the sine of the depression angle being fed to the lens drive (FMC servo amplifier).

The output of the servo drive amplifier is directed to a lens drive torque motor/feedback tachometer package to which a constant rate-of-rise, dual surface cam is coupled. Through a captive follower mechanism, the lens is driven at a rate proportional to the V/H ratio of the aircraft modified by the sine of the depression angle. Upon completion of the photo, the command to the servo is changed from a scan (rate) mode of operation to a position mode of operation whereupon the lens returns to its starting position awaiting the camera's next trip pulse from the CCP.

To prevent the lens from excessive travel over and above its mechanical limits of 1.5 inches, an electronic clamping circuit limits the maximum amplitude of the V/H signal generated by the CCP. When power to the camera is removed, a mechanical brake holds the lens in a locked position to prevent the lens from possible movement.

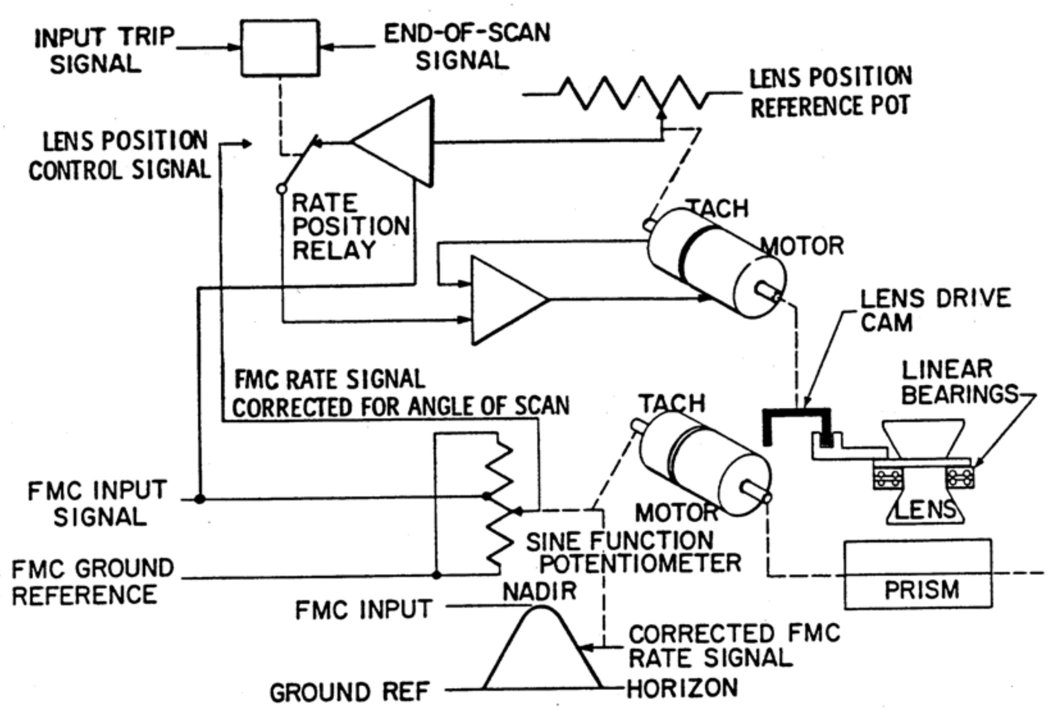


Figure 6. Lens/FMC Control Circuit

SELECTABLE SECTOR SCAN

The KA-91C camera features a mode of operation called *sector scan*. This feature allows the operator to change the angular coverage of the camera while in flight. The selection of the coverage can be made from either the camera or from the CCP. Two scan modes are currently available on the KA-91C camera. A "narrow" mode which covers 60 degs., and a "wide" mode which covers 93 degs. of ground coverage. Figure 7 shows the lateral coverage vs. scan angle for the two modes; figure 8 shows the flight line coverage obtainable at different altitudes for a 1,000-ft roll of film.

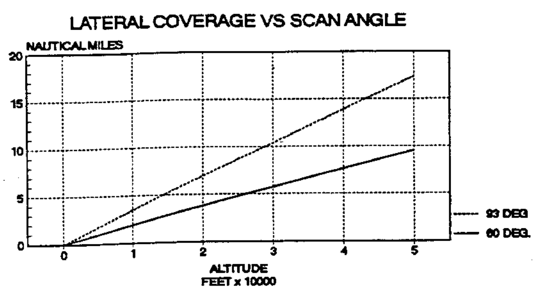


Figure 7. Lateral Coverage

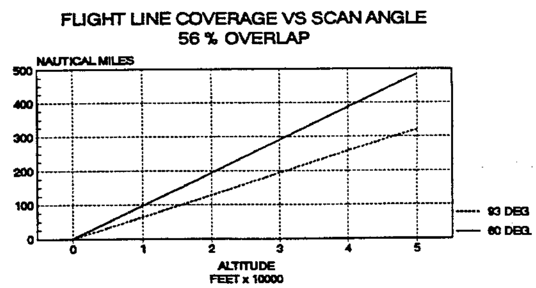


Figure 8. Flightline Coverage

The scan angle is controlled by digitally counting the number of turns of the metering roller. The 60° scan requires four turns of the metering roller producing an 18.8-inch photograph, while the 93° scan requires six turns and produces a 29.2-inch exposure. Unexposed space between the exposed frames is approximately 2 inches.

Selection of either the 60° or 93° scan can be accomplished in one of two ways. A three-position rotary switch is located on the upper right hand corner of the pan cone assembly pan adapter. Located directly under the switch knob is an instruction plate with the following nomenclature: N, W and R. With the switch knob pointing to N, the selected scan angle is 60°. With the knob pointing to W, the selected scan angle is 93°. With the knob pointing to R, control of the scan angle is from the CCP. Using the CCP scan select switch, the operator can select either the 60° narrow scan or the 93° wide scan. The selection of the 93° scan angle is accomplished from the CCP by the placing of a ground on pin f of the input CAMERA connector through the aircraft wiring from the CCP. Approximately 575 frames of 60° exposure, or approximately 380 frames of 93° exposure can be made on a roll of film.

Selection of scan angle is controlled by activation of relays on the lens and prism Circuit Card Assemblies (CCAs). The lens CCA, operating in conjunction with the camera's logic CCA, determines the metering roller count. The prism CCA selects the proper tap on a potentiometer located in the prism drive assembly, which determines the prism scan starting point.

ROLL STABILIZATION

While vehicle motion is a major detriment to good photographic performance, another contributor to photographic degradation is aircraft roll. Therefore, in addition to FMC, roll motion compensation is provided to correct for aircraft roll.

ROI has compensated for the rolling action of the vehicle in which the KA-91C by installing a roll rate sensing gyro. As shown in figure 9, the output of the gyro is summed with the prism rate drive signal and prism rate feedback tachometer to either increase or decrease the scan rate of the prism. The equation in the figure defines the compensation of the prism rate with the correction being one-half of the actual vehicle roll rate.

One benefit of using an internally mounted gyro is that the camera does not have to tie into aircraft systems. Also, the gyro measures the actual rate of the camera, which is important should the camera mounting employ an isolation system.

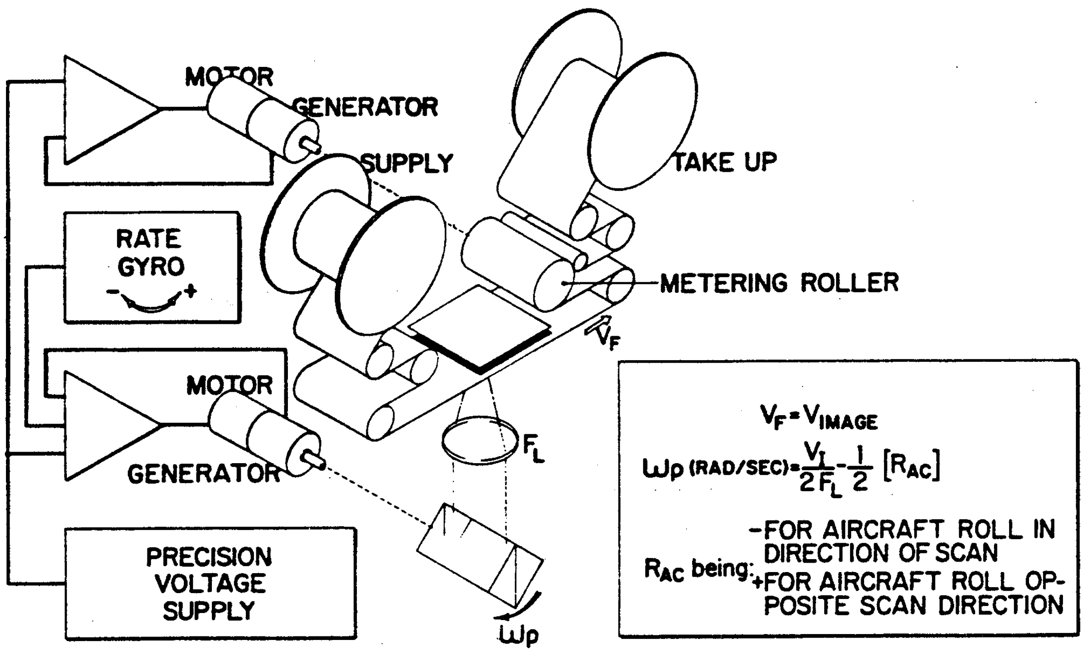


Figure 9. Film and Image Scan Synchronization

EXPOSURE CONTROL

To obtain optimum photographic qualities, an automatic exposure control has been incorporated into these cameras. The system features a closed-loop null detector system with a silicon photo sensor. Compensation for film type and/or filter type is performed using a multi-position switch located on the pan adapter. The switch is calibrated to be used with films with an AEI of from 1.5 through 300, and filter factors for either .6 Neutral Density, W-12 (yellow) and W-25 (red). The exposure control is active and varies exposure as required whenever power is applied to the camera.

Exposure is controlled by a set of parallel blades located directly in front of the film plane. The range of control can be varied between 1/100 and 1/1500 s with an accuracy of +/- 1/2 f/stop. Slit position is monitored by a feedback potentiometer mechanically connected to the gear train that controls the position of the shutter curtains with respect to each other.

The input to the potentiometer is a multi-voltage power supply of either 5, 10, or 20 VDC. The 5-VDC supply is used under normal operation. The output signal from the potentiometer is summed with the output signal from the silicon photo sensor at the exposure amplifier. This amplifier then activates either an increase or decrease relay which drives the exposure motor and ultimately the movable slit blade. This activity continues until the input to the exposure amplifier is balanced between the input from the feedback potentiometer and the photo detector. The 10 and 20-VDC references are used to increase the exposure one or two f/stops, respectively.

A cloud cover switch on the CCP is marked 0%, 25% and 50%. This switch is used to control the application of the reference voltage to the feedback potentiometer through two relays located on the exposure control chassis. The purpose of the cloud cover switch is to compensate for cloud conditions when flying above the clouds. When flying above the clouds, the photo detector would be seeing the brighter illumination from the clouds rather than the illumination from the ground, and would then reduce the camera's effective exposure time. Depending on the amount of clouds between the aircraft and the terrain, the operator will compensate for the clouds by activating the cloud cover switch to either the 25% or 50% position. When flying beneath the clouds, the switch should be left in the 0% position.

One additional feature of the exposure system on the KA-91C is that after each photograph is taken, the width of the slit is exposed on the film in the interframe space. This feature enables the operators and evaluators to determine the time of a given exposure. A slit width vs. exposure graph is shown in Figure 10.

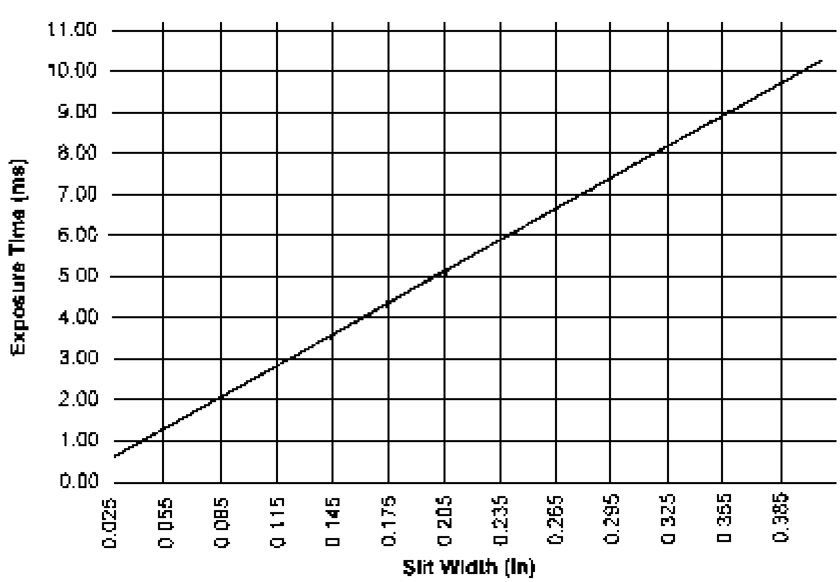


Figure 10. Slit Width Vs. Exposure